A Smart City Concept for Improving Alteration and Refurbishment of Buildings

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Abstract

The need for local councils, housing associations, housing developers and others in the UK and other developed/emerging economies with a relatively large portfolio of buildings to review their maintenance, alteration and refurbishment procedure constantly cannot be over-emphasized. As housing stock continue to age, the need to make them more sustainable in use and performance continues to increase as well and as such the demand to alter and refurbish continues to increase. Traditionally, alteration and refurbishment of the buildings have be carried out on the basis of need or by using a fixed (preventive or reactive) maintenance programme. However, the advent of Building Information Modelling (BIM), the use of smart devices, the Internet of Things and other smart city elements are now offering the industry the opportunity to leverage the potential of the smart city concept to explore the opportunities being offered. Based on an on-going research work that seeks to improve the building alteration and refurbishment process, this work uses a case study to demonstrate a conceptual approach that can enhance the maintenance and refurbishment programmes of properties based on the smart city concept. The concept examines the potential of property maintenance and refurbishment at a micro and macro level and highlights the perceived benefits. The direction of future work is also stated as part of the work as a precursor to engendering wider debate and implementation.

Keywords: Refurbishment, BIM, Smart Cities, Internet of Things, Smart Planning

1. Introduction

The need for local councils, housing associations, housing developers and others in the UK and other developed/emerging economies with a relatively large portfolio of buildings to review their maintenance, alteration and refurbishment procedure constantly cannot be over-emphasized. As housing stock continue to age, the need to make them more sustainable in use and performance continues to increase as well and as such the demand to alter and refurbish continues to increase.

Generally speaking, the United Kingdom like most of the developed world, is faced with massive housing and various property-related challenges (Fernandez, 2011). Whilst new stock is being built to account for these shortages, the process of alteration and refurbishment continues to become more popular where applicable and is forming a substantial part of the construction activities in those countries (Thiemann, 2010).

To this end, previous research work by Oloke (2015) had reviewed the potential of integrating some emerging technologies to propose a conceptual model that could be developed for the lifecycle design, construction, operation and disposal/ refurbishment of a facility or portfolio of properties. The management of Health and Safety throughout the building refurbishment project lifecycle is becoming pertinent for sustainable development as this is constantly evolving as a significant element of lifecycle processes relating to a facility. Using design/specification information from an alteration and refurbishment project case study, health and safety management information were collated and utilised as a basis for the development of the schematic of the proposed integrated platform as part of this work.

1.1 Aim and Objectives

To further the development of the on-going research work, this work seeks to improve the building alteration and refurbishment process using a fusion of those processes that facilitate the smart city concept. In the pursuit of this aim, the following objectives were achieved:

- The review of literature to establish the emerging concepts of Building Information Modelling (BIM), Internet of Things (IoT) and Smart Cities.
- The use of a case study to demonstrate a conceptual approach that can enhance the maintenance and refurbishment programmes of properties based on the smart city concept and;
- The development of a conceptual framework model that will form the basis of future application of the integrated system.

2. Traditional Alteration, Refurbishment and Maintenance of Buildings

It has since been established that need to adapt buildings and other structures to accommodate new uses and to upgrade building performance are major reasons for alteration and refurbishment projects (Fernandez, 2011). Research evidence continues to suggest that the complexity of the process remains a challenge for health and safety management amongst other things.

Traditionally, risk assessments and method statements underpin the implementation of a robust health and safety management system (Professional Guidance No.43, 2015). However, unless there is improvement in the integration and coordination of the process, the efficiency could be limited (McAleenan and Oloke, 2015). Similarly, alteration and refurbishment of the buildings have be carried out on the basis of need or by using a fixed (preventive or reactive) maintenance programme.

3. Emerging Concepts

The advent of Building Information Modelling (BIM), the use of smart devices, the Internet of Things and other smart city elements are now offering the industry the opportunity to leverage the potential of the smart city concept to explore the opportunities being offered

3.1 Building Information Modelling (BIM)

Continuing advancement in digitalised technology has brought about constant changes and innovations in each industry (Chong et al., 2017). As one of these key technologies seeking to lessen the impacts of global warming and growing environmental concerns, Building Information Modelling (BIM) is designed to positively contribute in sustainable life-cycle decisions with significant impact on our environmental, social and economic needs (Azhar et al, 2010; Parn et al, 2017). The dynamic digital environment provided by BIM manages to effectively store, share and integrate all the essential building information from conceptual design and pre-construction stages throughout the entire life-cycle of a building within a three-dimensional computer model (Parn et al, 2017). Such information technologies enable exceptionally detailed fragmentation, as encompassing many aspects and systems of a facility, and simultaneously managing to retain all the ongoing processes together, as describing a construction entity within a single model, thus aiming to purposefully achieve a set target (Azhar, 2011; Turk, 2016). The very valuable virtual process of BIM for design, construction, operation and maintenance of buildings allows professionals to create and reinvent sustainable designs that improve cost-savings of a built facility, and, what is tremendously important, all of the project team members (owners, architects, engineers, contractors, subcontractors, suppliers) to collaborate more intensely and efficiently together, comparing to the impractical traditional processes (PAS 1192-6, 2018). Various analysis have reported significant return on investments in time which is a significant economic benefit and driving key to consider the importance of BIM-assisted designs in such practices (Bryde et al 2013). The use of BIM is also perceived to be advantageous owing to "higher-quality deliverables", excellent time management, accurate cost estimation, reduced project costs and higher net savings, better understanding through real-time visualization, instant conflict detection and low percentage of documentation errors, contingencies, risks and unexpected alterations (Ghaffarianhoseini et al, 2017). There is little implementation of BIM for existing buildings. While BIM processes are established for new buildings, most existing buildings are not yet maintained, refurbished or deconstructed with BIM (Parn et al, 2017).

3.2 Internet of Things (IoT)

The Internet of Things (IoT) refers to the interconnectivity of all types of devices across a wide range of geographical boundaries in addition to the people that use them. is facilitating the intersection of people, data and intelligent machines and transforming processes and industries. This in turn is boosting efficiency and productivity internationally. Developers currently use mobile apps that aid the collection of different kinds of data and access expert services remotely through mobile devices. This means that the monitoring, maintenance and performance of structures can be improved through cloud computing and big data management. SKF is one of the companies providing a multi-faced application of IoT (SKF, 2018).

According to Jacob Morgan at Forbes IoT is "The concept of basically connecting any device with an on and off switch to the internet (and/or to each other)," and involves every device you can think of, including consumer electronics such as cellphones, coffee makers, washing machines, headphones and wearable devices, as well as bigger machines such as manufacturing equipment. Future

predictions are that nearly all technology-based devices will be equipped with internet connectivity as a means of contributing to the growing IoT (ibid).

The concept involves the use of specialist software to collect data from various internet-enabled machines and devices used at a location or several locations in order to help improve efficiency. Such software (e.g. EAM) can be used to improve the supply chain or to test how well certain parts are working. The latter helps engineers or facilities managers realize when a part needs maintenance or simply needs to be replaced. Regular maintenance is a must for large equipment and heavy machinery, but it's made easier when there's software that can monitor each piece of equipment and detect problems when they happen, rather than finding said problem after the fact. This presents a great potential for large structures with complex components like HVAC, Lifts, etc and simpler structures that have these across a large portfolio stock.

Additionally, widely-scaled EAM solutions can compare data from different facilities. The data collected from every device in every facility can be compared to find which processes a particular facility may be better at than another and why that's the case. Despite this, the most exciting aspect of EAM is not only the ability to improve maintenance and the supply chain, but the ability to reduce environmental impact. By constantly monitoring the machines and devices involved in industries such as manufacturing, these corporations can increase their focus on improving sustainability on a large scale, hopefully leading to much greener processes in the near future. (Select Hub, 2018).

As discussions about the Internet of Things (IoT) captured the interest of industrial companies of all sizes over the past few years, the biggest caveat has been the conceptual nature of industrial IoT applications. In other words, there are lots of possibilities for IoT to discuss, but little in terms of real world applications. But that's quickly beginning to change with nearly every passing quarter as more companies roll out official versions of IoT applications they've been testing.

3.3 Smart Cities

In the smart city concept, numerous stakeholders are involved and at present there are obviously limits to how far this coordinated approach can advance. Even within a building, there are big challenges to resolve when integrating services such as HVAC, lighting, room booking, security or fire protection. For a start, these may well be the responsibility of different departments.

On a wider scale in a 'real' city, these divisions are likely to be multiplied many times. Most cities will have numerous 'stakeholders'. Even where there is a well informed and pro-active city leadership, they will need to accommodate political colleagues and rivals, public officials, services, utilities and businesses and media. Several other parties , the Mayor has limited political power and budgeting resources and needs to cooperate not just with a council representing numerous parties, but with more than 30 London Borough's each with their own powers and agenda, not to mention the UK national government. It is also pertinent to note that issues such as cyber security and data protection, which already loom large for building managers, are substantially more complex at a city level, and with much more potentially at stake. This is already a challenge for Building Managers.

4. Case Study

This work therefore uses a case study to demonstrate a conceptual approach that can enhance the maintenance and refurbishment programmes of properties based on the smart city concept. It is based on an on-going research work that seeks to improve the building alteration and refurbishment process.

The case study project involves the conversion of a 3-Unit Industrial building (named Unit 1, Unit 2

and Unit 3) to a brand new multipurpose facility. The project entailed the demolition of Units (1) and (2) and the refurbishment of Unit 3. Whilst the refurbishment of Unit 3 is to lead to the development of a new hall; the sites of the demolished Units 1 and 2 are to be used to build a new multi-purpose hall.

As shown in Figure 1, the site is underlain by major public sewers and as such the enabling works for the demolition and the preparatory works necessitated a coordinated Risk Assessment and Method Statement development. Figure 2 further shows an aerial view of the building indicating the section of the building (Unit 3) is to be retained. Unit 3 lies between Gridlines 1 and 7 on the plan shown in Figure 1.

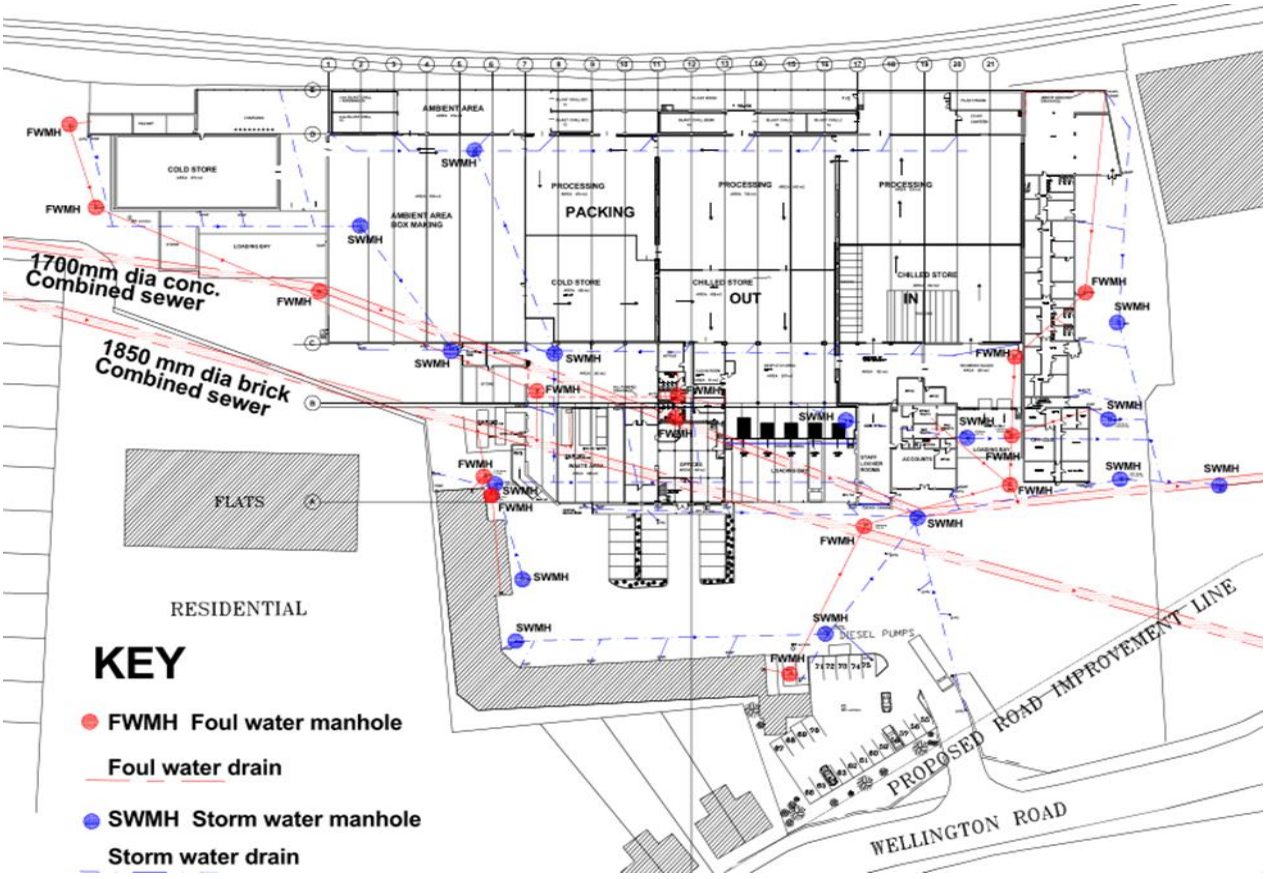

Figure 1: The Case Study Site Layout

4.1 Work Activities

In order to achieve the brief, there was a need to sequence the works linearly through enabling works (including roof replacing on unit 3), deconstruction/ demolition, reconstruction, fit-out, handover and occupation. This study covers the completed work activities up to the deconstruction/demolition work activities. Each of these activities were awarded as a separate contract that allowed the Client to achieve the project in packages.

4.2 Risk Assessments and Method Statements

The linearized sequence of work was also used to conduct the risk assessment and method statement. Each of the work packages was undertaken by a contractor who in turn produced their own risk assessment and method statements. These are described as follows:

4.2.1 Work Package (WP) 1: Enabling Works (Roofing and ceiling)

The WP1 involved installing new timber batten on existing roof of Unit 3, laying mineral wool insulation and over cladding with metal roofing sheets. This WP will also include the installation of the suspended ceiling upon completion of construction works. Table 1 highlights the risks, risk centres and mitigation measures as identified for this WP.

WP1 Method Statement
In order to properly manage WP1 work-related risks, the WP1 was executed by ensuring that: timber battens were supplied, lifted to roof top and installed with screws in addition to installing the insulation and metal sheets at the same time. The fork lift was guided by appropriately trained operative to facilitate the accurate delivery of materials. The ceiling installation is also to be done from movable scaffolds as part of the second phase of WP1 which takes place towards the end of the construction Work Package. Currently these method statements are undertaken and stored in a 'traditional' setting through the creation of standardised documents which are stored as part of the contract information.

Table 1: Risks and Mitigation Measures for WP1

Risk	**Risk Centre (s)**	**Mitigation Measure (s)**
Mounting the roof on the ladder	Operative can be at risk	Climbing caution needs to be taken
Lifting timber, insulation and metal sheets unto the top of the existing roof	Operative can be at risk	Handling caution needs to be taken
Working from scaffold to install ceiling	Operative can be at risk of falling down	Scaffold to have metal guards
Handling and heavy lifting	Operatives at risk of injury at Work at Height risks	Min 2 operatives to lift heavy materials.

4.2.2 Work Package (WP) 2: Deconstruction/ Demolition

The demolition WP involved the demolition of the two units identified as Units 1 and 2. Figure 2 shows the work in progress with Unit 3 left undemolished as originally designed. Being an old concrete-steel framed structure, the process commenced with deconstruction of the steel elements and cladding elements and then the demolition of the concrete elements. The ground floor slab was left to the last stage so that it can provide a good access platform for demolition plant and equipment. Table 2 highlights the risks, risk centres and mitigation measures as identified for this WP2.

Figure 2: Commencement of Deconstruction/ Demolition of Units 1 and 2 and Retention of Unit 3 in Progress

5. Proposed Conceptual Framework

BIM involves creating a holistic information resource that also combines 3D geometric models, 2D data sources, documents, spreadsheets, and more into a single repository. BIM is also not best realised by a single, lowest-common denominator data model imposed on every organisations in the supply chain. BIM is a business process, not a technology and has since been used to organize several layers of information relating to a development (Eadie et al., 2013). Oloke (2015 and 2017) had proposed a model for incorporating health and safety information into a BIM model for Refurbishment of Buildings. This case study information has thus been used to modify the model to engender an integrated risk assessment and management on such projects. Figure 3 shows the modified model which is being proposed as a conceptual integrated risk management model and how it is to incorporate elements of the Risk Assessment from each phase of the work. The developed BIM model is as shown in Figure 4 which is now ready to be populated with relevant risk and safety information.

Although this development is still being tested on a single building/ development, the concept proposes to extend the potential application to property maintenance and refurbishment at a micro and macro level. Figure 5 shows a block diagram of this proposal. The Figure shows how a clod-based server is proposed to host access to several BIM Models belonging to a portfolio of properties of a landlord/ housing association, city council or others.

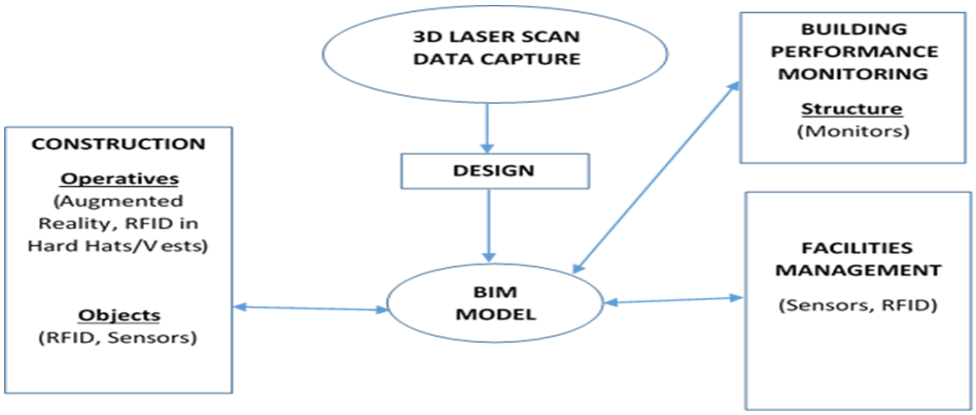

Figure 3: Proposed Conceptual Integrated Framework Model for Alteration and Refurbishment Projects (Adapted from Oloke (2015)).

Figure 4: Developed BIM Model of the Refurbished Unit 3

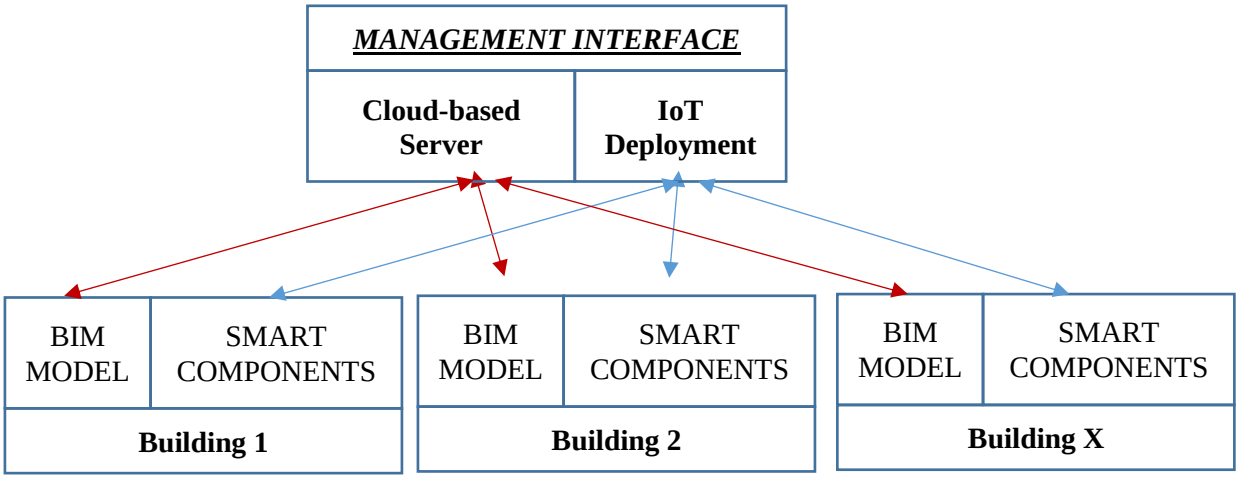

Figure 5: Block Diagram of an Integrated Cloud-based Management Model

6. Envisaged Benefits

It is envisaged that once the system is fully deployed, the entire lifecycle of property refurbishment and maintenance will be greatly facilitated. In many countries, health and safety management is now mandated by legislation (e.g. CDM Regulations in the UK). The requirements are based on the principle of allocating Duty of Care to every duty holder involved in the refurbishment and maintenance process throughout the phases of a project Not only will the proposed system facilitate this, but it will also enable a more efficient achievement of the entire process.

7. Conclusions and Recommendations

As housing stock continue to age, the need to make them more sustainable in use and performance continues to increase as well and as such the demand to alter and refurbish continues to increase. Previous work had reviewed the potential of integrating some emerging technologies to propose a conceptual model that could be developed for the lifecycle design, construction, operation and disposal/ refurbishment of a facility or portfolio of properties. As the management of health and safety throughout the project lifecycle is becoming more pertinent, this work concentrated on developing the conceptual model for managing health and safety on refurbishment and maintenance of projects. The proposed model incorporates the use of BIM, Smart Technologies and IoT to propose an integrated platform for the refurbishment and maintenance process.

It is hereby recommended that future work should entail the further development of the model using additional case studies to finalize the design and testing of the concept.

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